Troposphere-to-stratosphere transport mechanisms: Insights from recent measurements on the role of direct convective injection into the stratosphere

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Introduction and Motivation

Question: Have we observed evidence of direct convective dehydration or hydration of the stratosphere?

Understanding what impact global climate change will have on the stratospheric water vapor budget is critically important both accounting for its radiative impact and its potential to significantly enhance the catalytic destruction of ozone through heterogeneous loss processes.

Direct convection into the stratosphere has been proposed as both a mechanism to dehydrate [Danielsen E. F., 1982; Danielsen, E. F. *et al*., 1993] and to hydrate (e.g. Dessler and Sherwood, 2004) the stratosphere, but what evidence is there of dehydration or hydration in water vapor measurements?

Sonde Data

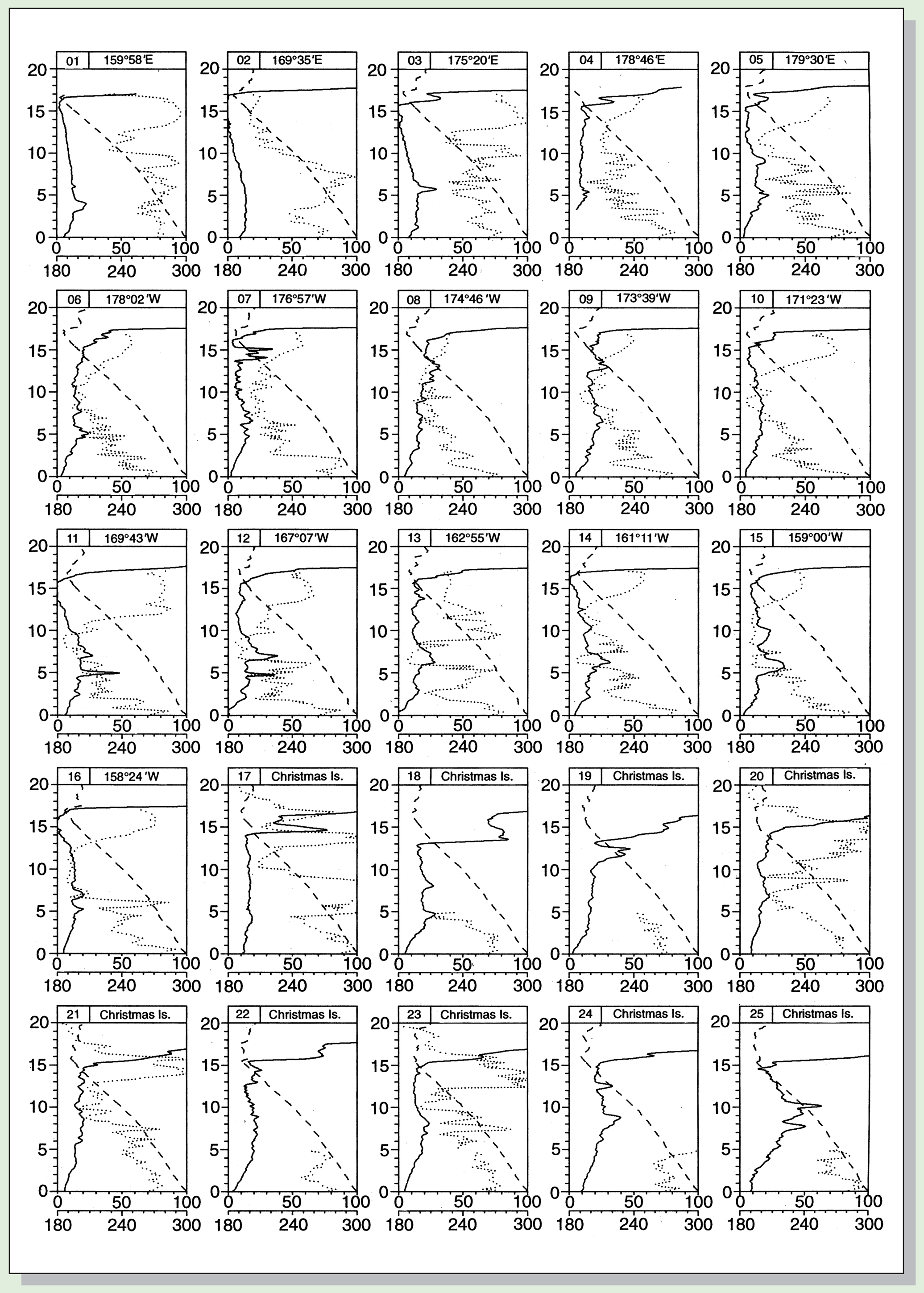

Figure 1. Verticle profiles of temperature from 240 to 300 K (dashed lines), ozone from 0 to 100 nmol/mol (solid lines) and relative humidity (rh) over water above 0°C and ice below 0°C (dotted lines) [Kley *et al*., 1996]. Only rh in panels 17, 20, 21, and 23 are derived from frostpoint data. The others use HUMICAP sensors. The altitude in km is given on the ordinate. The data are taken in March 1993 in the Western tropical Pacific along the cruise track of the Vickers.

- The ozone profiles indicate that the very strong convection, in evidence for much of the month, reaches but does not cross the cold-point tropopause.
- The chemopause as indicated by the sharp increase in ozone marks the top of gas phase transport (and the top of any existing cloud as well).
- So, even with the observation of consistently strong convection, any potential dehydration (not observed) would be below the tropopause.

In Situ Aircraft Data

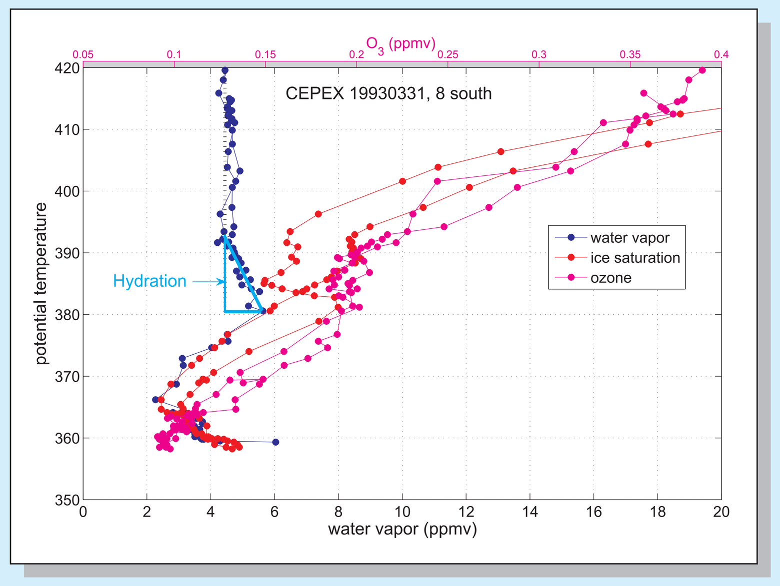

Figure 2. *In situ* water vapor and ozone data taken during a typical dive at 2 South during one of eight flights on the NASA ER-2 from Fiji (17°S, 175°E) during the Central Equatorial Pacific Experiment (**CEPEX**) mission.

- Water vapor (blue) tracking ice saturation (red), suggesting the existence of a cloud.
- No evidence of convective dehydration in the stratosphere.
- Evidence of hydration above the (apparent) cloud as outlined by the cyan triangle.

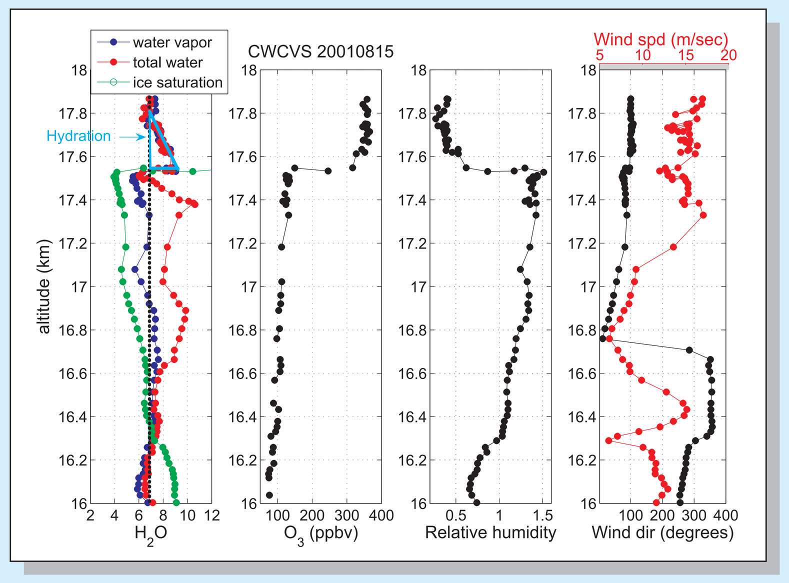

Figure 3. Plots showing measurements of water vapor, total water, ozone, relative humidity and wind direction at the tropopause during the August 15, 2001 flight of the Clouds and Water Vapor in the Climate System (**CWVCS**) mission out of Costa Rica.

- The top of the cloud in the left-hand panel is coincident with the sharp transition in ozone and relative humidity in panels 2 and 3 respectively, and the sharp increase in water vapor above this transition region.
- Panel 4 illustrates a gradual change in wind direction through the tropopause region, allowing for a potential relationship between the cloud and the air above it.
- Because these data (as opposed to the CEPEX data) have total water to identify the presence of a cloud, interpretation of the data is clearer than for the CEPEX case.
- We observe thin cirrus with no evidence of dehydration, which could occur if ice particles grow and sediment out.
- As in Figure 2, we see hydration above the cloud top.

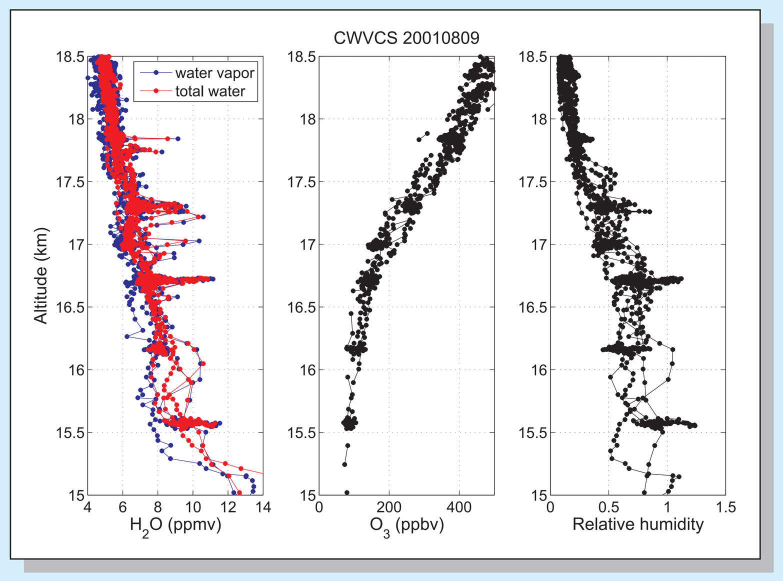

Figure 4. Plot showing measurements of water vapor, total water, ozone and relative humidity at the tropopause on the August 09, 2001 **CWCVS** flight.

- This flight has similar amounts of water vapor to that of August 15 but warmer temperatures in the tropopause region.
- The air is typically subsaturated, so no cirrus are detected.
- Hydration, apparently from convection, is clearly observed by both water vapor and total water instruments.
- The ozone profiles are not perturbed, suggesting evaporating ice particles are the source of the high water vapor.
- These convective events were not seen during CEPEX, but except for the typically single dive during each flight, the ER-2 cruised at about 20 km during that mission.

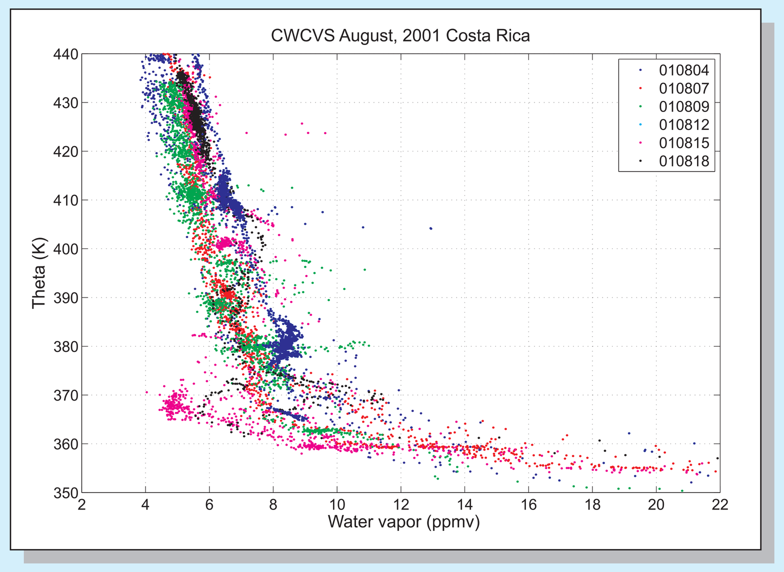

Figure 5. Plotted are all the water vapor data during **CWVCS**.

- Convection is observed above 420 K (18.5 km) on August 15th. While average water vapor observed at 380 K is close to 8 ppmv, we do not have evidence to indicate convective influence. (e.g. isotope data).

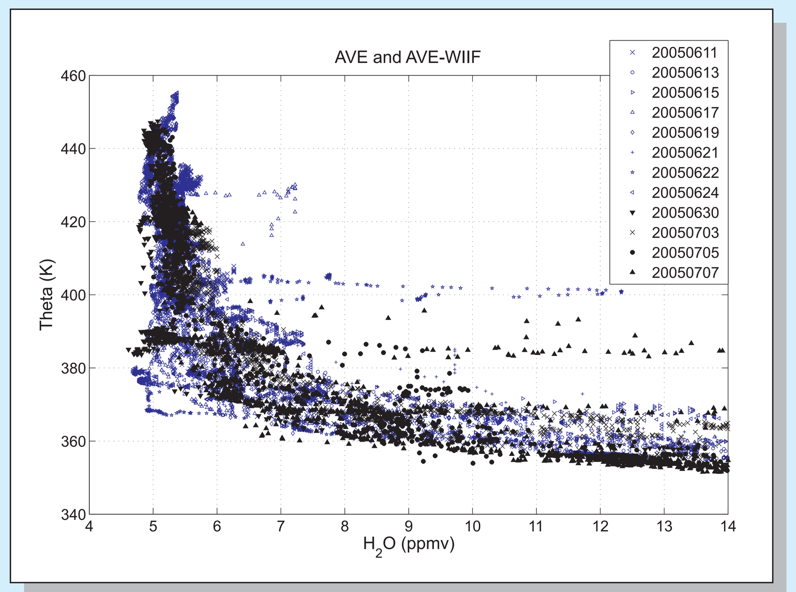

Figure 6. Plotted are water vapor data taken during **AVE** and **AVE-WIIF**.

- Flight trajectories over the Midwestern United States often sampled air downstream of strong convection.
- The highest convective event was observed at 18.2 km on June 17th.
- Water isotope measurements during AVE-WIIF are consistent with convective influence on the high water observed in the lowermost and lower stratosphere. [Hanisco *et al*., 2006].

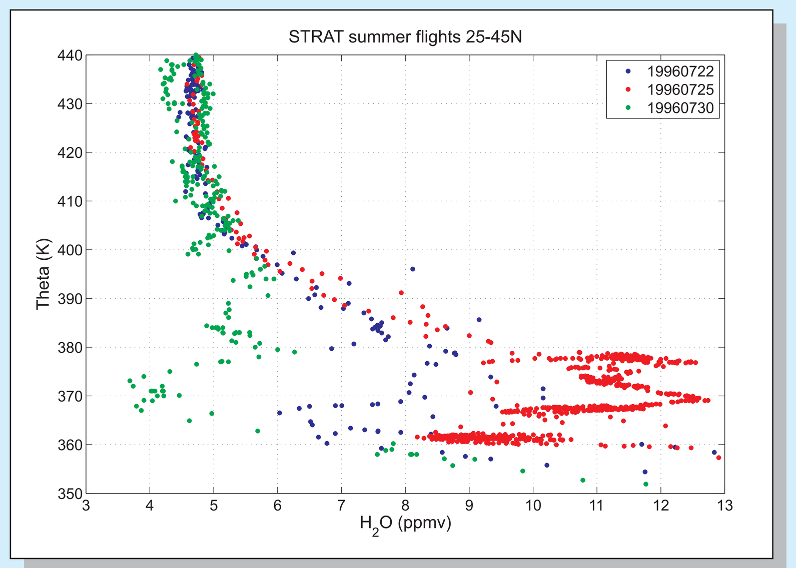

Figure 7. Plots of water vapor during taken in the summer of 1996 during **STRAT**.

- Data illustrate the apparent effect of convection off the Baja peninsula across the 390 K surface.

What can we conclude?

- *In situ* data illustrates that during northern midlatitude summer convection hydrates the stratosphere both in the tropics and northern midlatitudes.
- But there are not enough data to determine if it is quantitatively important?

What do satellite data show?

- To explore this we first look at PDFs of deviations from mean water vapor data during CWCVS, AVE, and AVE-WIIF to see the fraction of data points impacted by convection.

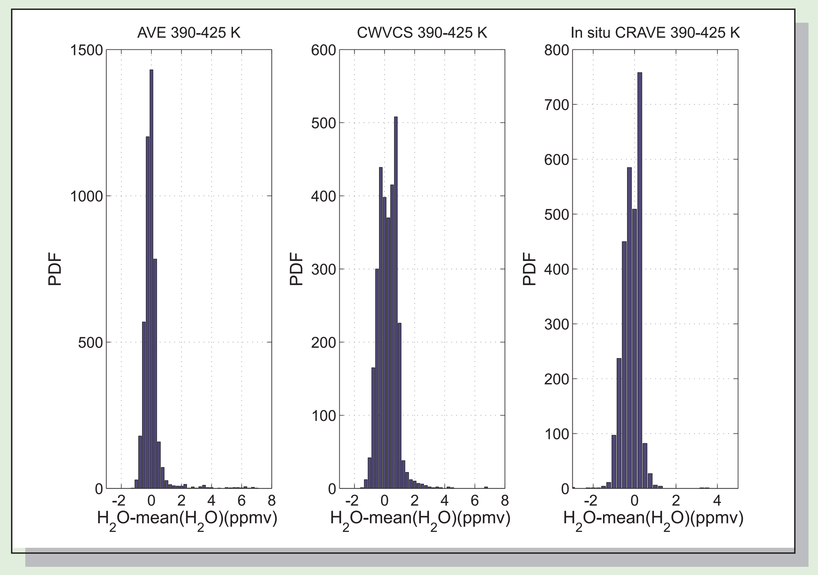

Figure 8. PDFs of deviations from mean water vapor data in the lower stratosphere during AVE, CWCVS, and CRAVE.

- Data show frequency of observed data moistened by convective events in the stratosphere during AVE and CWVCS, but absent during CRAVE.

MLS Data

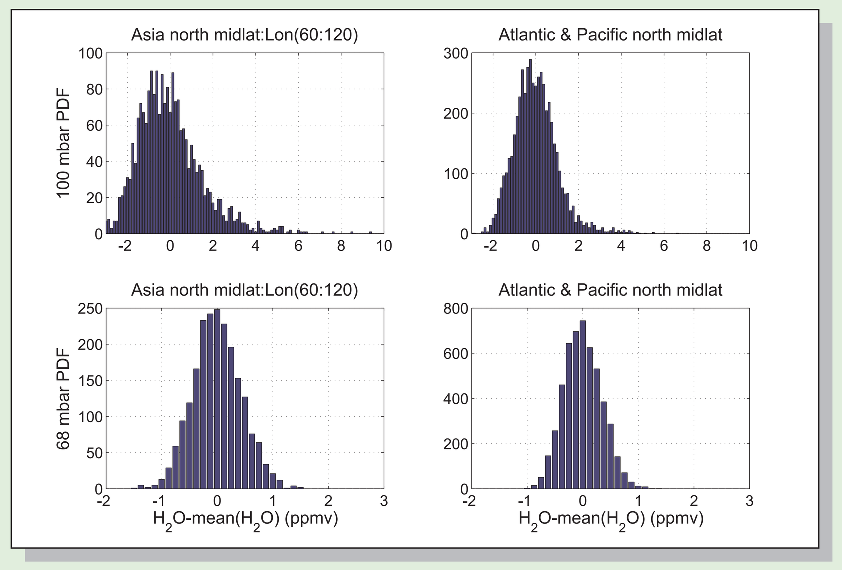

Figure 9. Sample PDFs of deviations from mean water vapor data in the lower stratosphere from MLS data at 68 and 100 mbar during July and August 2005.

- Data show evidence of convection on the 100 mbar surface but not on the 68 mbar surface.
- More convection is seen in northern midlatitude data over Asia.
- PDFs using subtropical data are similar; PDFs (not shown) indicate less hydration in the tropics.

Conclusions

- *In situ* and satellite data show evidence of hydration from direct convection into the stratosphere.
- Data do not appear to show convective influence is a significant factor in the stratospheric water vapor budget.
- Higher resolution MLS data may allow for a clearer separation of lower stratospheric and tropospheric data in the tropics.

References

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